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JOHN R. MOHLER, Chief

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METHODS FOR CLOSE AUTOMATIC CONTROL OF INCUBATING TEMPERATURES IN LABORATORIES.

By JOHN T. BOWEN, *Technologist, Dairy Division.*

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The automatic control of temperature within close limits is very important in many lines of commercial work. It is of special importance, in fact, is a necessity, in laboratories where chemical, bacteriological, and physiological investigations are conducted. In many instances success in the maintenance of cultures depends upon the ability continuously to maintain practically constant temperature. Pathogenic microorganisms, as a rule, do not grow except within very narrow temperature limits, the optimum temperature being about 37.5° C. (99.5° F.).

The Bureau of Animal Industry, United States Department of Agriculture, produces tuberculin on a large scale; about 16,000 culture flasks of 300 c. c. capacity are maintained to produce the required quantity. The tubercle bacillus is very sensitive to temperature changes. In order to obtain the best growths, therefore, the temperature during the period of incubation should be maintained practically constant at the optimum of about 37.5° C. To hold the temperature in all parts of the chamber approximately constant requires considerable care, especially if the chamber is large.

Other work carried on by the bureau includes the study, by bacteriological means, of other diseases of domestic animals. The

cultures made from the diseased tissues are usually incubated at about the same temperature as that mentioned for the tubercle bacillus. There are, however, certain thermophilic organisms that may be encountered in bacteriological investigations of diseased tissues, and in order to be able to investigate these organisms smaller compartments are provided. These are located inside the larger incubating compartment and are furnished with separate heating devices. The system used for controlling the temperature is identical with that of the larger room, the controlling device being adjusted to maintain the temperature at a higher point.

CONSTRUCTION OF TEMPERATURE-CONTROL COMPARTMENT.

In the control of temperatures the proper construction of the compartment is of equal importance with that of the controlling apparatus. The walls, floors, and ceiling should be so constructed as to minimize the transfer of heat from the inside to the outside of the room, thus economizing on the quantity of heat required to maintain the desired room temperature. Not only will the proper construction of the room reduce the quantity of heat necessary to maintain the desired temperature, but should the supply of heat be discontinued the insulated walls of the room will assist in holding the temperature near the desired point for a considerable time. Figure 1 shows the rate at which the temperature falls when the source of heat is entirely cut off. The curve shows that for a period of approximately one week the drop in temperature was only about 6° C. The temperature surrounding the incubator room—that is, the temperature in the laboratory during this time—averaged about 21.1° C. It is obvious, therefore, that in a well-installed compartment cultures may continue to grow several days after the supply of heat has been discontinued.

The dimensions and construction of incubating compartments used in laboratories of the bureau at Washington are illustrated in figure 2. The finished inside dimensions of the rooms are 7 feet wide by 7 feet 6½ inches deep by 8 feet 5 inches high. The capacity of each room, in terms of standard 300 c. c. flasks, is about 2,600. In all there are 7 rooms of these dimensions.

CONSTRUCTION OF ROOM.

Floors.—On the laboratory floor one course of 1-inch cork board was laid down in hot asphalt. All transverse joints were broken and all joints were slushed with hot asphalt and made tight by butting the sheets of cork board closely together. The top surface of the cork board was flooded with hot asphalt about one-eighth inch thick, and directly on top of this a wearing concrete floor was laid, the thickness of the floor being 2 inches in the center of the room and 3 inches

at the walls. The floor was sloped to the center to facilitate cleaning and disinfecting.

Walls and ceiling.—Expanded-metal walls and ceiling were constructed, as shown in figure 2. These consisted of 1-inch channel studs, tied at the floor and ceiling and thoroughly crosstied. The studs were covered with No. 24 gauge high-rib expanded-metal laths which were used instead of channels in order to give greater strength.

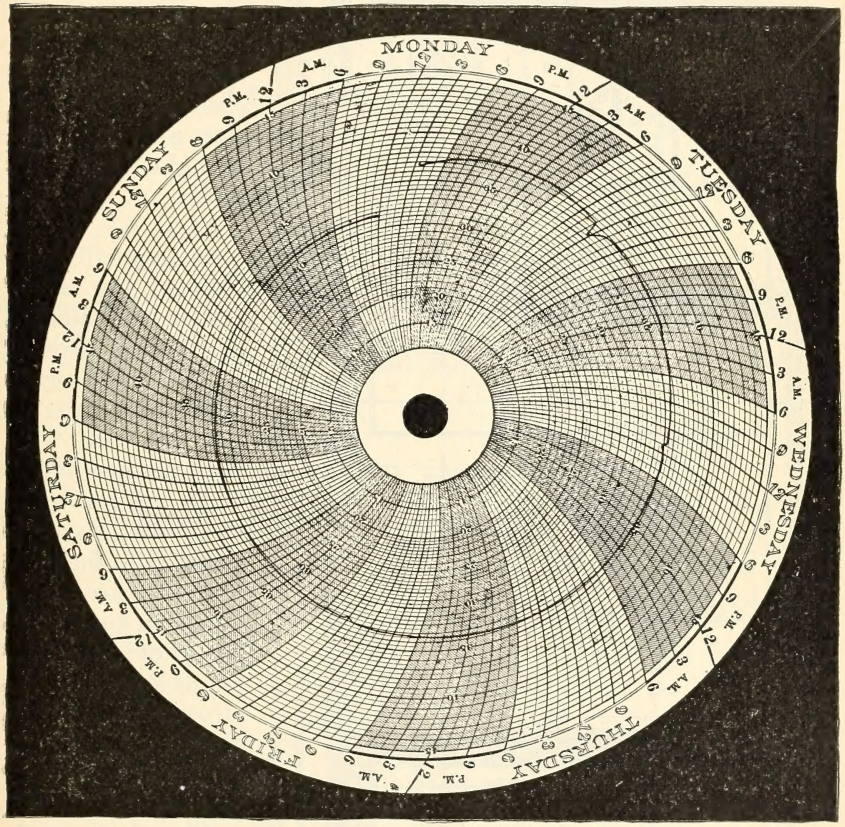

FIG. 1.—Chart showing drop in room temperature for one week, with heat supply entirely shut off.

Directly on the expanded metal a ½-inch course of cement mortar was applied, mixed in the proportion of 1 part of Portland cement to 2 parts clean, sharp sand.

While the mortar was green a course of 2-inch cork board was erected on it and the joints were slushed with hot asphalt. Against the exposed surface of the cork board a Portland-cement plaster finish about one-half inch in thickness was applied in two coats. The first coat, about one-fourth inch in thickness, was mixed in the

proportion of one part Portland cement to two parts of clean, sharp sand, and it was rough scratched. After this coat had thoroughly dried, the second coat, approximately one-fourth inch in thickness and mixed in the proportion of one part of Portland cement to one and one-half parts of clean, sharp sand, was applied and brought to a float finish.

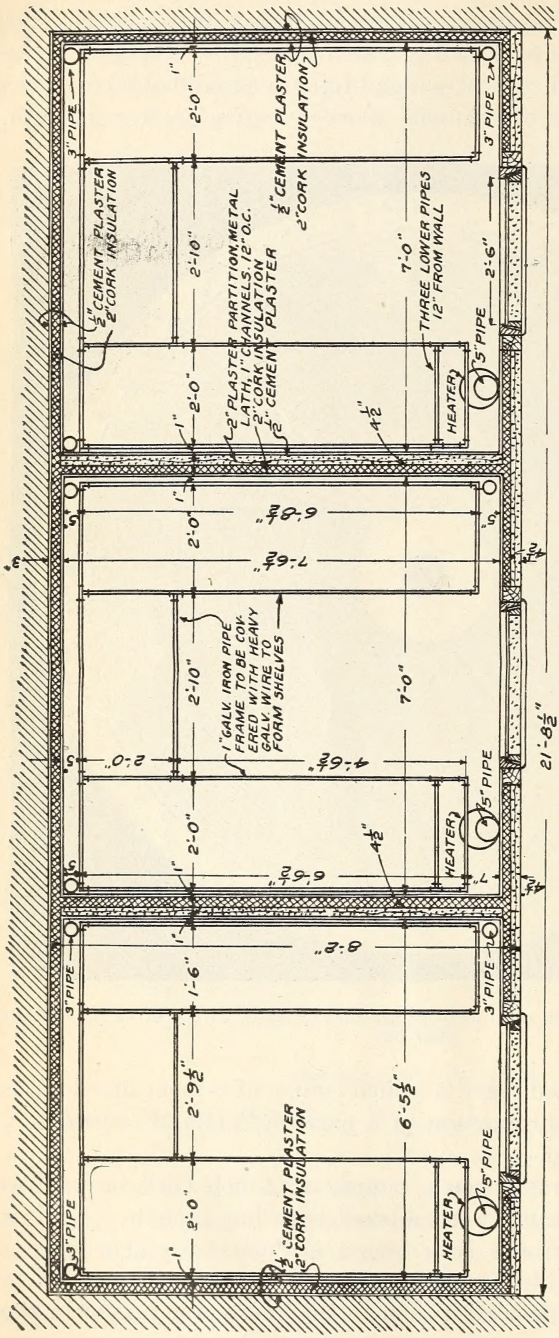

FIG. 2.—Plan showing the dimensions and construction of incubating compartments used in laboratories of the Bureau of Animal Industry.

Shelves.—Shelves were originally constructed (fig. 2) of 1-inch galvanized-metal pipe, covered with galvanized-wire mesh made of No. 16 wire with four meshes to the inch. The wire mesh was securely soldered to the pipe frame, care being taken to leave no projections that might cut or scratch those working in the compartment. It was found, however, that the wire-mesh covering offered more or less resistance to placing the trays on the shelves, and it was subsequently removed and the trays containing the flasks are now placed directly on the pipes. All the trays containing the

flasks are of the same size and fit on the pipe frame. Where different-sized crates are used, however, the wire covering is advisable.

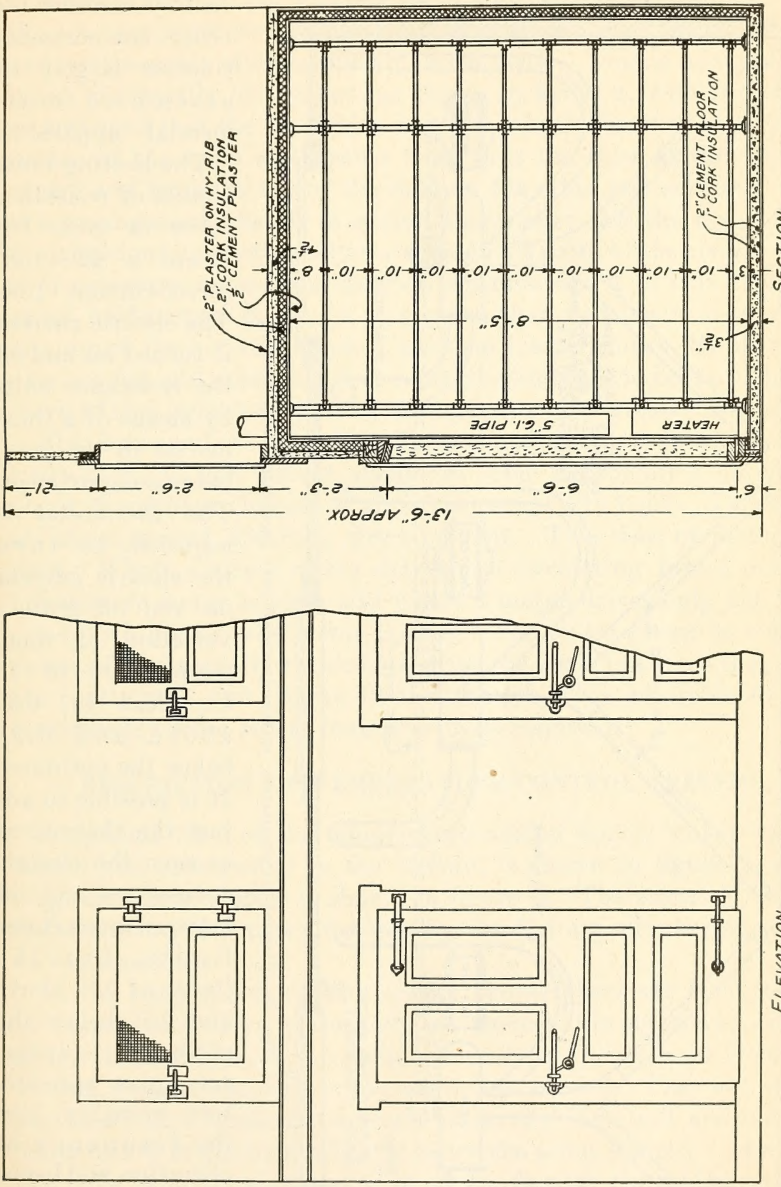

FIG. 3.—Vertical transverse section through incubating compartment and a partial exterior elevation.

HEATING EQUIPMENT.

Electricity is used in all cases as the heating medium. Two systems of temperature control, however, are used. The temperature-control

apparatus for the first incubating compartment was designed and for the most part constructed in the bureau. The temperature-control system for the other compartment consists largely of assembled commercial apparatus.

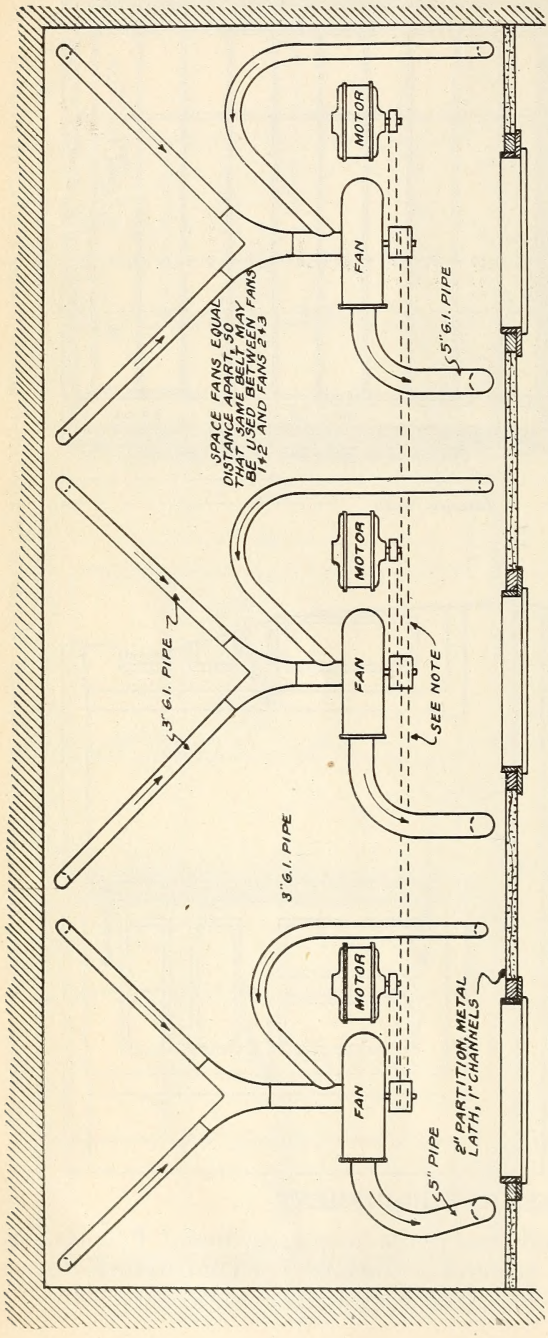
SPACE FANS EQUAL DISTANCE APART, SO THAT AIR MAY BE USED BETWEEN FANS 1 & 2 AND FANS 2 & 3
MOTOR
FAN
5" G.I. PIPE
3" G.I. PIPE
SEE NOTE
3" G.I. PIPE
MOTOR
FAN
5" PIPE
2" PARTITION, METAL LATH, 1" CHANNELS

FIG. 4.—Plan of air-circulatory system installed over incubating compartment.

The heating units consist of resistance tubes or coils fed from a 220-volt, direct-current line. The electric current is turned on and off the resistance units by means of a thermostat in the incubator compartment. The thermostat is adjusted to turn the electric current on and off with a variation of room temperature of 1° C., that is, 0.5° above and 0.5° below the optimum. It is possible to adjust the thermostat to turn the electric current on and off between much closer limits, but the limits of 0.5° above and 0.5° below the optimum temperature give satisfactory results, and the frequency of operation and hence the wear on the controlling apparatus are decreased. The temperature-control equipment

designed by the bureau demonstrated on tests that the temperature inside the room could be maintained between limits of ±0.1° C.

In order that all parts of the room may be kept at approximately the same temperature it is necessary to provide means for thoroughly and continuously stirring the air in the room. This is accomplished by an electrically driven fan, as shown in figure 4, with the piping so arranged that the air is blown down over the heating coils in one corner of the room and drawn from near the floor at the opposite corner and from the top of the room at the other two corners. With this arrangement the air is stirred thoroughly and the temperature is maintained approximately the same in all parts of the room. Since it is necessary to operate the fan continuously it is belt-driven at about half-normal speed, or at a speed that will insure a thorough mixing of the air and hence a uniform temperature. By using an oversize fan and operating it at reduced speed the chances of a breakdown of this important part of the equipment are greatly lessened.

The fans used in these installations operate at a speed of about 1,400 R. P. M. and deliver about 190 cubic feet of air a minute, or about 26 complete changes of air in the room every hour. The motors are shunt-wound, 230-volt, direct current. Two sizes of motors are used. Where a single motor drives two circulating fans a one-half horsepower motor is used, and where a motor drives only one fan a one-fourth-horsepower motor is used. The motor power is much in excess of that actually required to drive the fans; but since they operate continually and receive little attention, it is advisable to have considerably more power than is actually required.

DESCRIPTION OF TEMPERATURE-CONTROL SYSTEMS.

A general view of the temperature-control board, which was designed and constructed in the bureau, is shown in figure 5, and a diagram of the system is shown in figure 6. The electrical connections covering the motor for driving the fan are simple and require no explanation.

In the temperature-control system proper there are four coils of 110 ohms each. Two of the coils are connected in series and directly across the main line, with a switch for cutting the coils out if desired. In cold weather the coils are brought into service. They are so proportioned that when continuously in service they will maintain the temperature in the room slightly below the point desired. The other two coils, which are connected in series, furnish the additional heat required to bring the temperature of the room up to the desired point. The latter two coils are connected to and operated by the controlling system. These coils are connected through the relay to the other side of the 220-volt line through a variable resistance in series with the instrument. This resistance is sufficient to reduce the voltage in

the relay circuit to four volts, and thus prevent arcking and burning the thermostat and relay contacts. Condensers are placed in the circuits where shown (fig. 6) for the purpose of absorbing the inductive discharge from the coils when the circuits are broken.

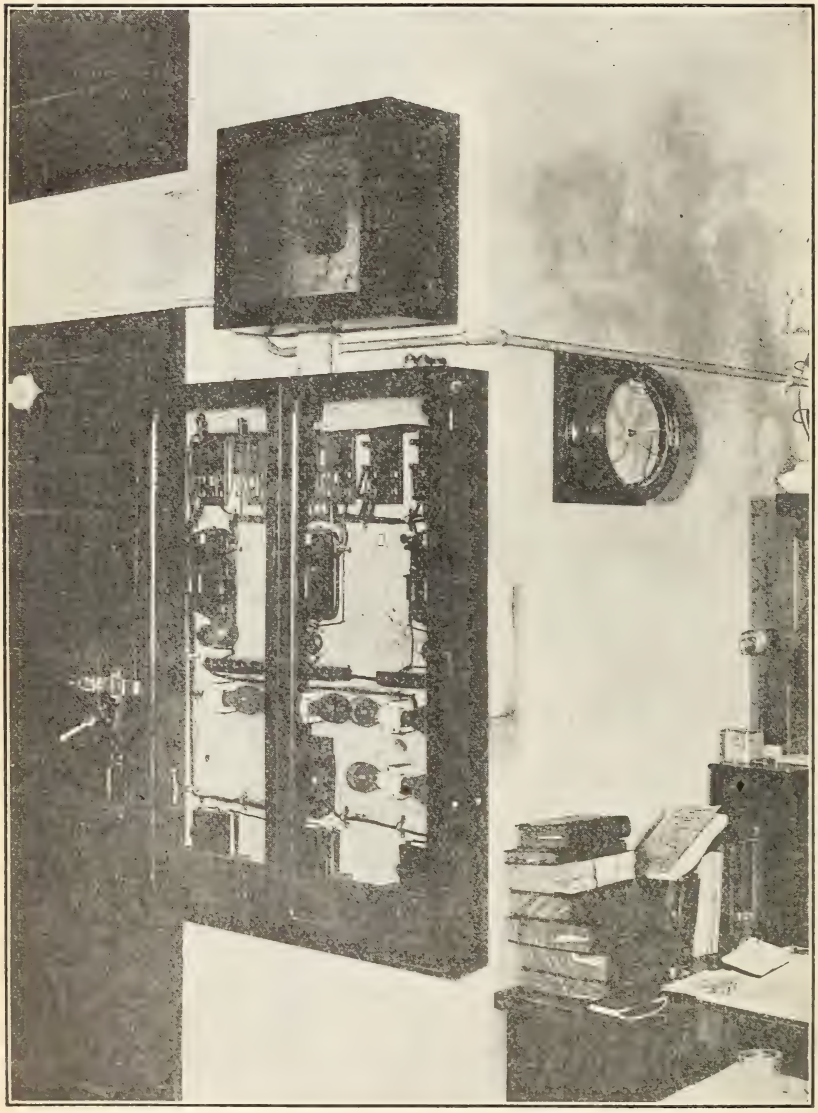

FIG. 5.—Temperature-control board of incubating room in Pathological Division.

The relay is connected for reverse action: that is, when the electric circuit is completed through the thermostat, owing to rising temperature in the room, the relay operates to break the main heating-coil circuit and thus cut off the supply of heat. On the other hand, when the relay circuit is broken in the thermostat, owing to a lowering

temperature in the room, the relay closes the heating-coil circuit. The overload device, shown in the diagram, has for its object the cutting out of the whole system in case the temperature-control apparatus fails to operate. In principle it is identical with the tempera-

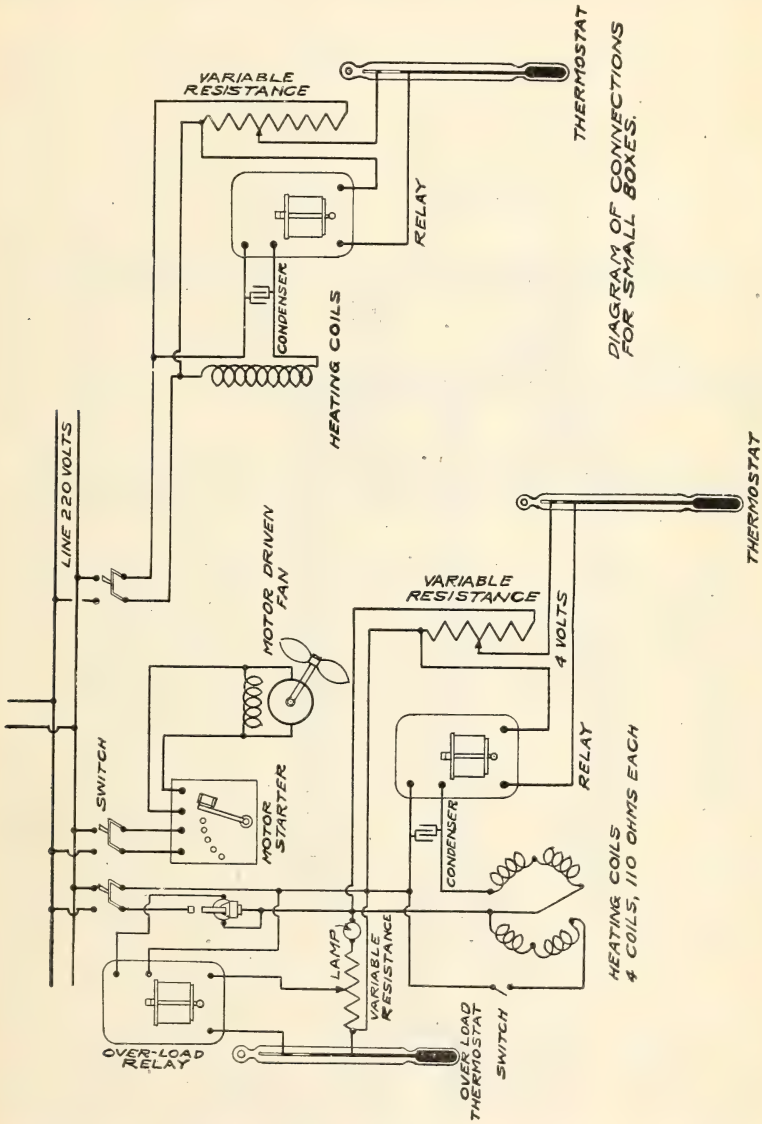

FIG. 6.—Wiring diagram of Pathological Division temperature-control system.

ture-control equipment. The overload thermostat is adjusted to close the electric circuit through the overload relay at a room temperature a few degrees above the normal operating temperature, the relay in turn breaking the circuit through the overload coil in the main line, thus cutting off the electric current in the entire system.

The heat-control system installed in the small high-temperature boxes, which are used for the investigation of thermophilic organisms, is identical with that used in the large room, except that on account of the small size of these boxes no means are provided for circulating the

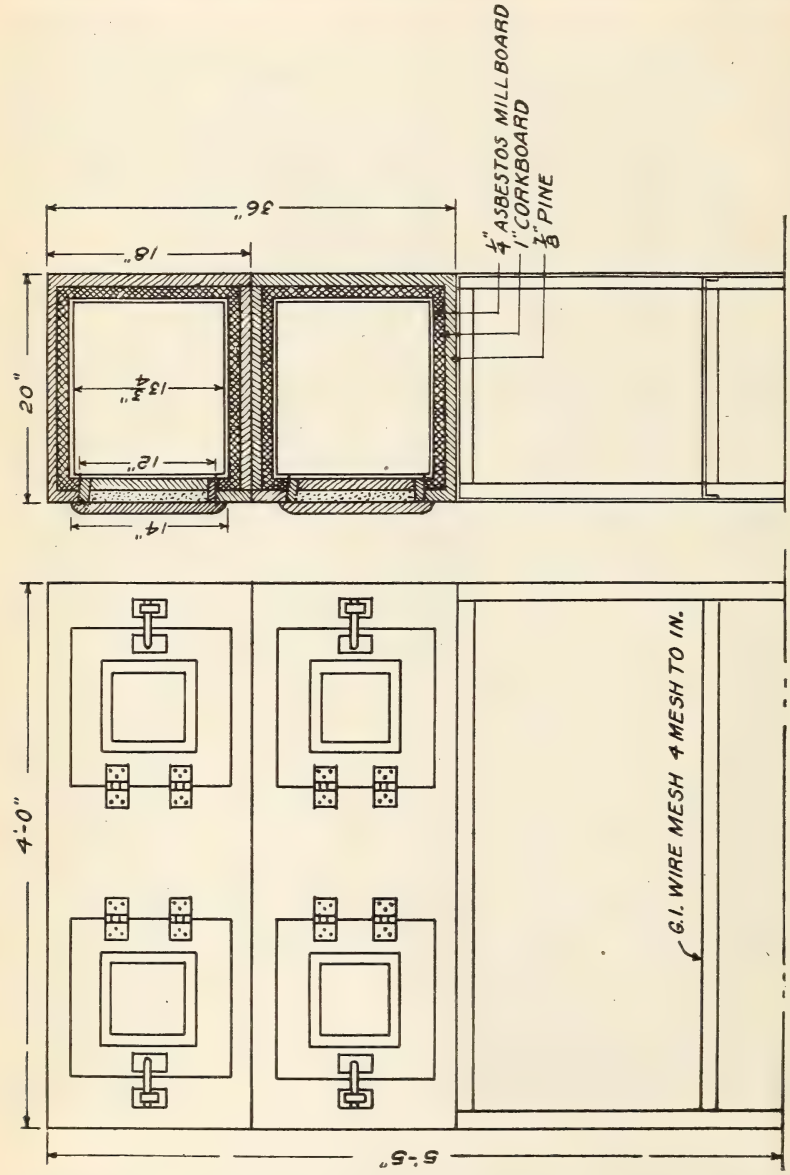

FIG. 7.—Plan showing dimensions and construction of small high-temperature boxes for Pathological Division.

inclosed air. These small boxes, the construction of which is shown in figure 7, are placed inside the large room; consequently the temperature surrounding them is that of the large room, 37.5° C. (99.5° F.). Owing to their small size and to the fact that their temperature

is maintained only a few degrees above that of the surrounding air, only small-capacity resistance units are required.

The special thermostat used in the incubator room is shown in figure 8. It is capable of making and breaking the electric circuit on a variation in temperature of about 1/100 of a degree F. Temperature adjustments are made by transferring mercury from the small reservoir to the capillary tube, and vice versa.

A general view of the temperature-control boards made up of commercial apparatus is shown in figure 9, and a diagram of the electric connections in figure 10. Six rooms are equipped with this apparatus. Referring to the diagram (figure 10), one side of the line is connected directly to the heating coil and from the heating coil to the line-magnet coil. The current in this coil is controlled by the pilot coil, which in turn is controlled by the thermostat. When the pilot circuit is closed through the thermostat the pilot coil is energized and closes the circuit through the line coil, which acts to close the line circuit through the heating coils. When the temperature in the incubation room rises to the upper limit the thermostat makes contact with the stop point, thus breaking the pilot circuit and opening the line coil, and hence the current in the heating coils.

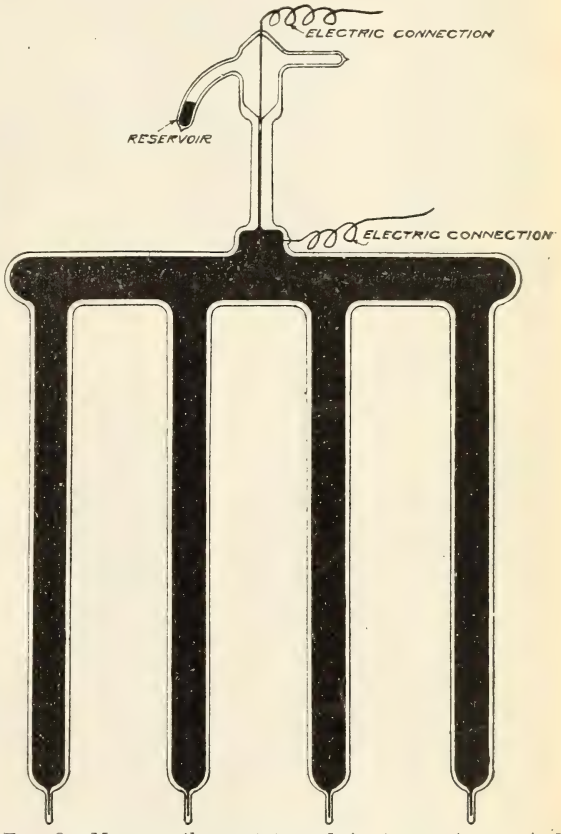

FIG. 8.—Mercury thermostat used in temperature-control system of Pathological Division.

TEMPERATURE RECORDERS.

Each incubation room is fitted with a continuous 7-day recording thermometer. The recording elements are mounted on the wall outside the room and the capillary passes through the wall, the bulb

being located near the top and in the center of the room. The charts taken from the recorders are examined and any variations in temperature beyond the prescribed limits are noted with the time at which the variations occurred. With these data at hand it is nearly always possible to find the cause of an excessive variation in tem-

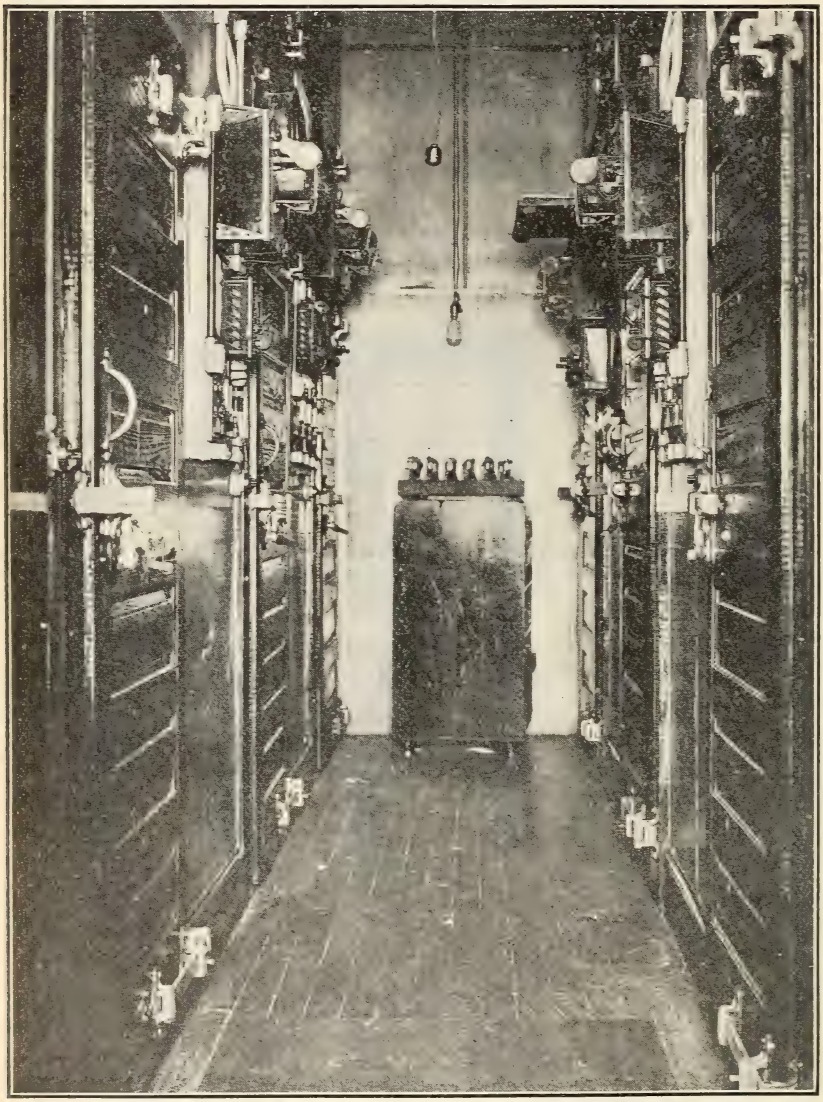

FIG. 9.—The temperature-control boards used by the Biochemic Division.

perature and also to fix the responsibility, if any is due. The mere fact that a permanent, continuous, and exact record is kept of the temperature conditions inside the incubator room is a stimulus to those in charge to do their best to maintain the conditions desired.

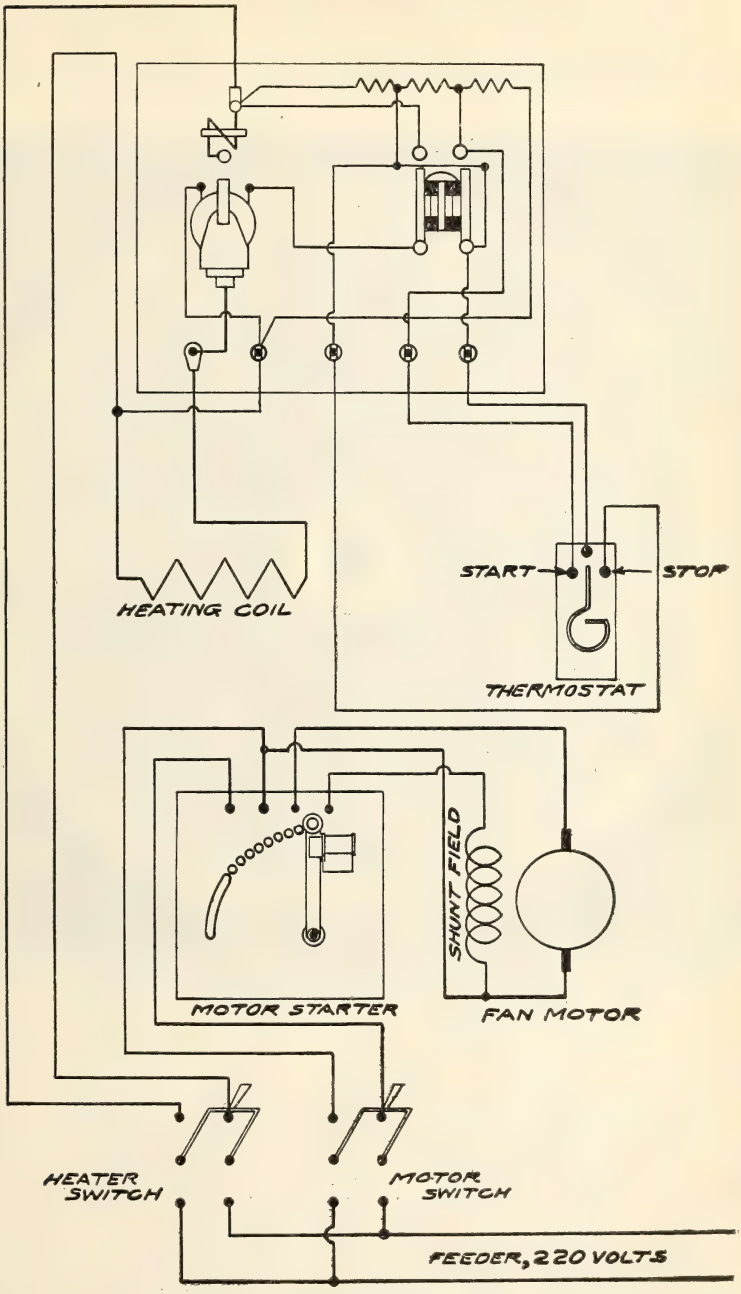

FIG. 10.—Wiring diagram of temperature-control system in Biochemic Division.

The value of a continuous-temperature record in the process of incubating cultures is great. Such records are not only of value in showing the temperature at all times throughout the period of incubation, but they may be dated and filed for reference, thus making it possible to determine with accuracy the temperature maintained in the incubating process on any previous date.

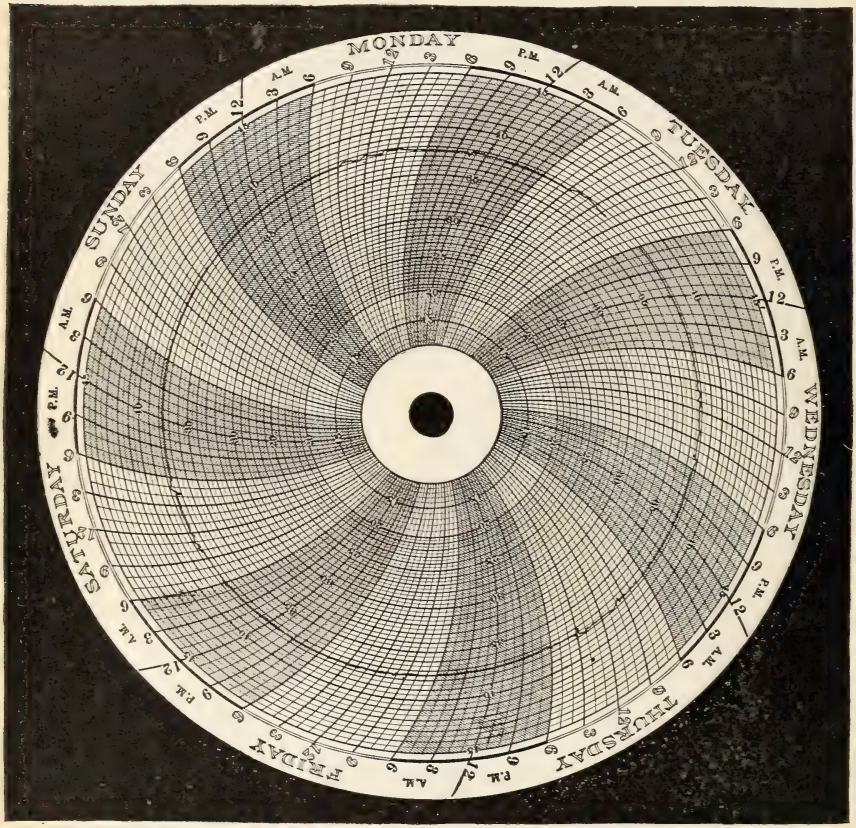

FIG. 11.—Chart showing the temperature maintained in the incubating room of the Pathological Division, January 22 to 29, 1918. Note that night temperatures especially are practically without fluctuation.

The chart in figure 11, taken from the incubator room equipped with the temperature-control system designed in the bureau, shows the temperature maintained for the week January 22 to 29, 1918—typical of the winter season. Attention is invited to the fact that during the night periods, when the room is closed, there is scarcely any variation in the temperature. During the day periods, however, when the door is opened for storing or taking out specimens, temperature variations occur. But in no instance do the variations exceed 1° C., and they exist for only a few minutes at a time. Even

these temperature variations may be materially lessened if the door is quickly opened and closed and kept closed while storing or removing specimens. A similar chart, figure 12, covering the week August 6 to 13, 1918, shows the results obtained during a typical summer period. The incubator room was entered only about twice during this week; consequently the temperature was maintained practically constant throughout the period.

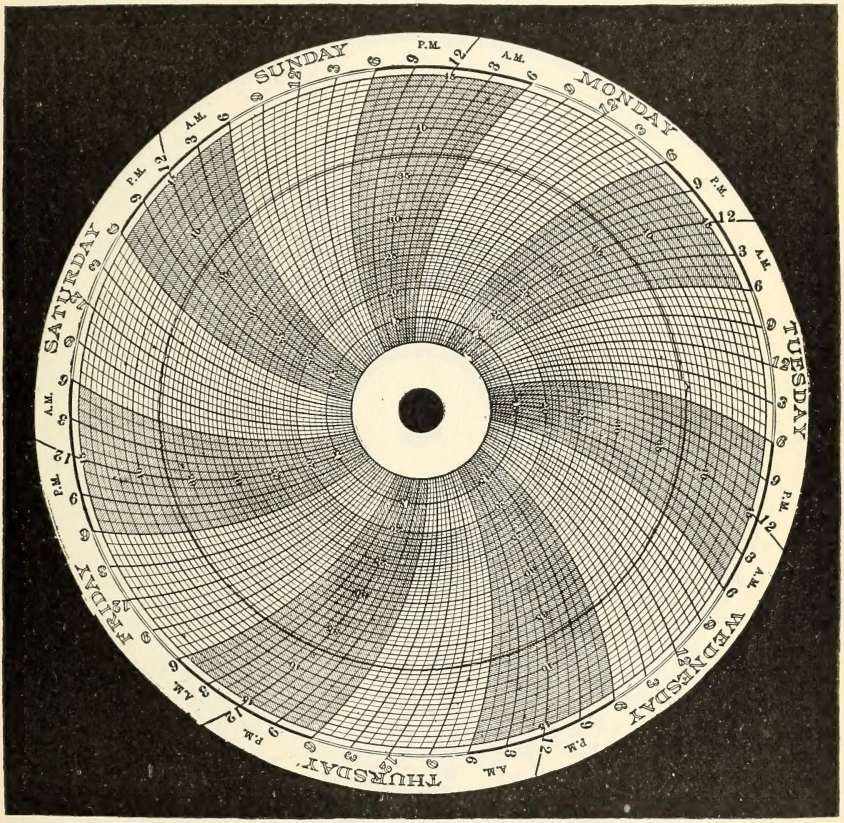

FIG. 12.—Chart showing temperatures maintained in incubating room of Pathological Division, August 6 to 13, 1918. Note that variations are exceedingly small.

The chart in figure 13 was taken in one of the incubator rooms equipped with a control system made up largely of assembled commercial apparatus. The curve shows that while the average temperature was about that for which the control was adjusted it was not so uniform as the temperatures shown in the previous charts. While this latter temperature-control system is not so sensitive or reliable as the former, and hence requires closer attention and more frequent adjustments, it has the advantage of being assembled from commercial apparatus.

COST OF OPERATION.

The cost of electric energy for operating the heating equipment and the motor-driven circulation fan at 6 cents a kilowatt hour averages about 50 cents a day of 24 hours for each room.

Prior to the installation of the present incubating rooms a large number of gas-heated incubators were used, the temperature being controlled by means of a bimetallic thermostat which regulated the

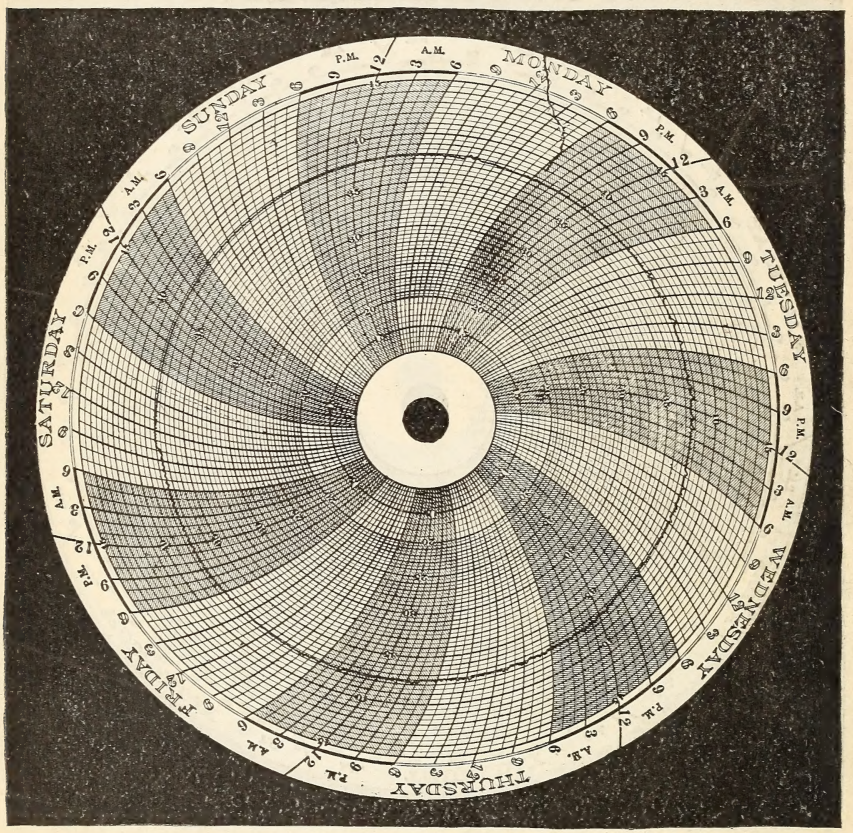

FIG. 13.—Chart of temperature maintained in incubating room, Biochemic Division, April 7 to 14, 1919. The system of control used is not so sensitive as that used in the Pathological Division.

flow of gas. These incubators occupied a large floor space, the control of temperatures was poor, and the fire hazard was great. With the present installation of incubating rooms the capacity has been about doubled and the space occupied has been reduced about one-half. Furthermore, the cultures have grown better than ever before, a result mainly of the very uniform temperature which has been maintained in the incubating rooms.